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(54) **THERMAL TUBE ASSEMBLY STRUCTURES**

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(58) **Field of Classification Search**

CPC H05K 7/20127; H05K 7/20145; G06F 1/187; G02F 2201/36

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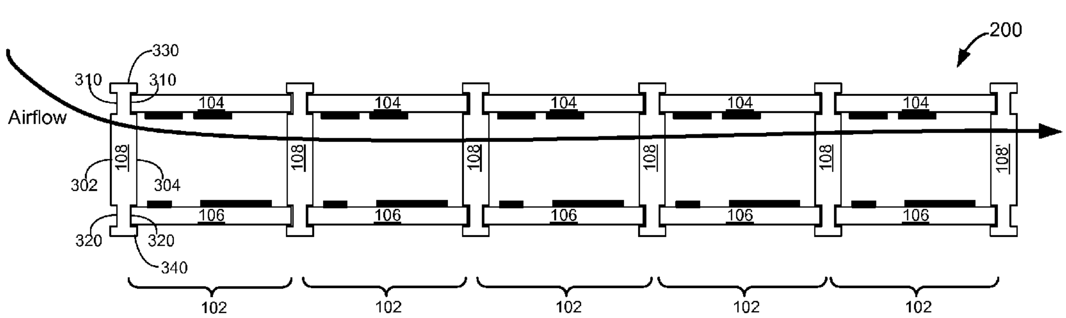
(57) **ABSTRACT**

Various embodiments described herein disclose systems, methods and/or devices used to dissipate heat generated by electronic components of an electronic assembly that further includes a first assembly rail, a top circuit board and a bottom circuit board. The first assembly rail includes a first card guide structure and a second card guide structure that are arranged on a first side of the first assembly rail near two opposite ends of the assembly rail. The top and the bottom circuit boards are mechanically coupled to the first and second card guide structures of the first assembly rail, respectively. The top circuit board is parallel to the bottom circuit board, and separated from the bottom circuit board by a predefined distance. The first assembly rail, the top circuit board and the bottom circuit board together form a channel there between for receiving a heat dissipating airflow.

20 Claims, 7 Drawing Sheets



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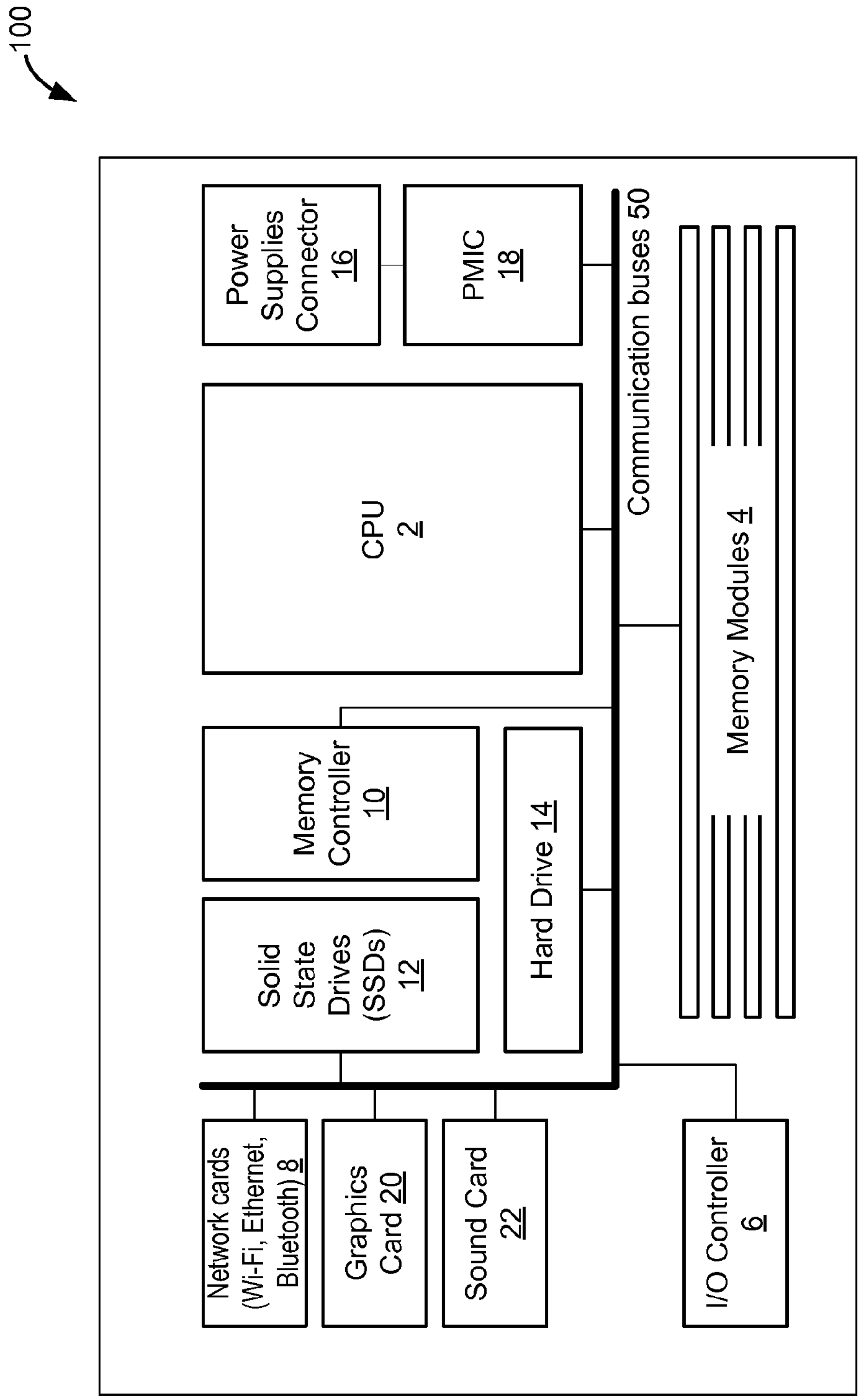

100
Power Supplies Connector 16
PMIC 18
CPU 2
Communication buses 50
Memory Controller 10
Hard Drive 14
Solid State Drives (SSDs) 12
Memory Modules 4
Network cards (Wi-Fi, Ethernet, Bluetooth) 8
Graphics Card 20
Sound Card 22
I/O Controller 6

FIG. 1

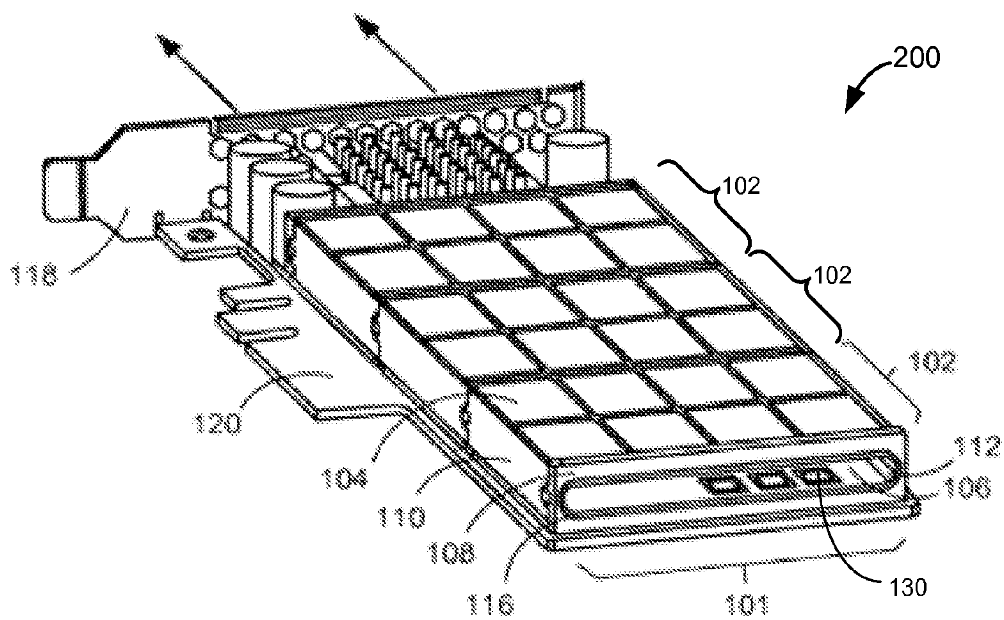

200
102
102
102
118
120
104
110
108
116
101
130
112
106

FIG. 2A

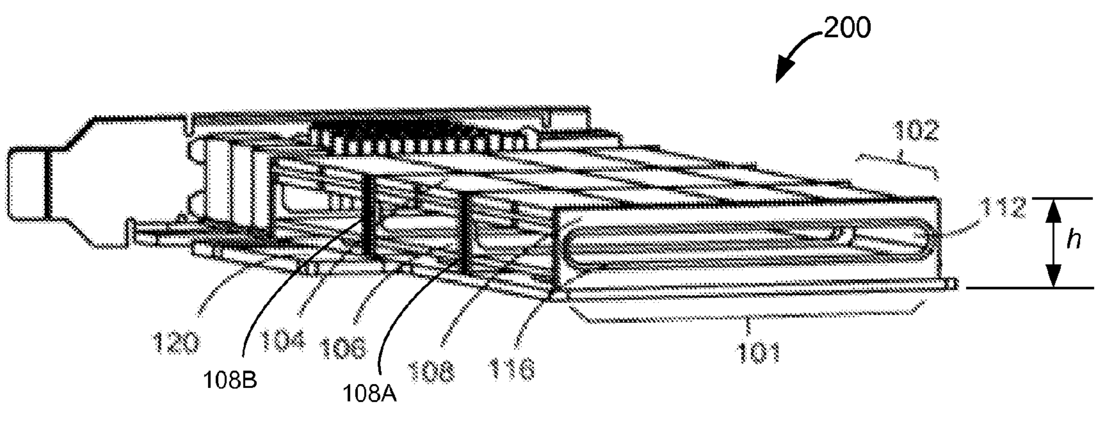

200
102
112
h
120
108B
104
106
108A
108
116
101

FIG. 2B

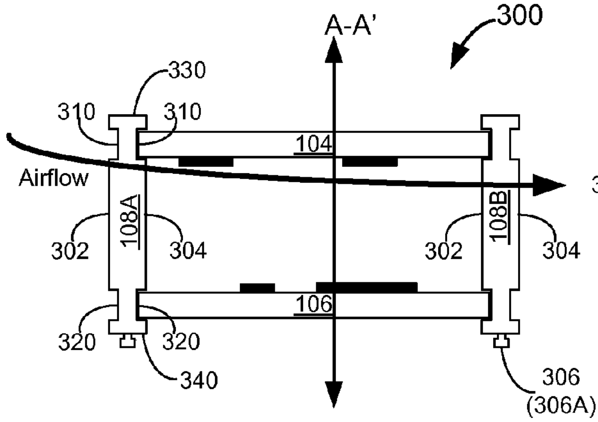


FIG. 3A

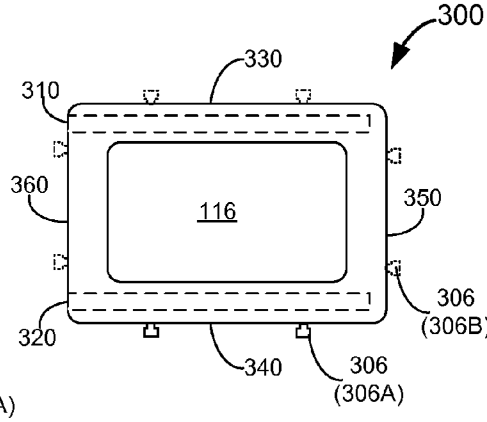


FIG. 3B

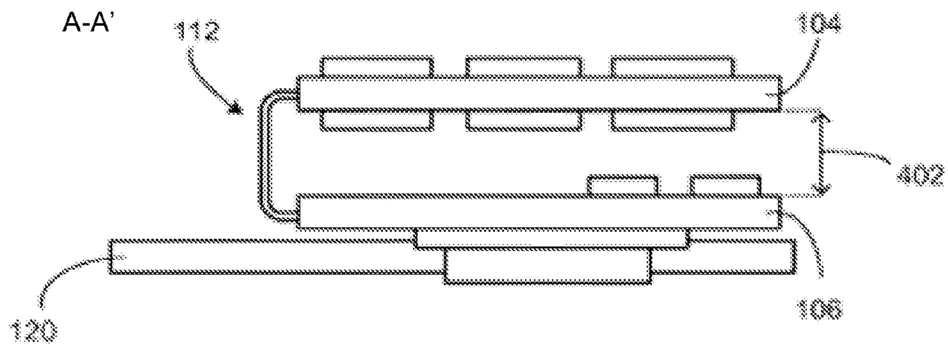


FIG. 3C

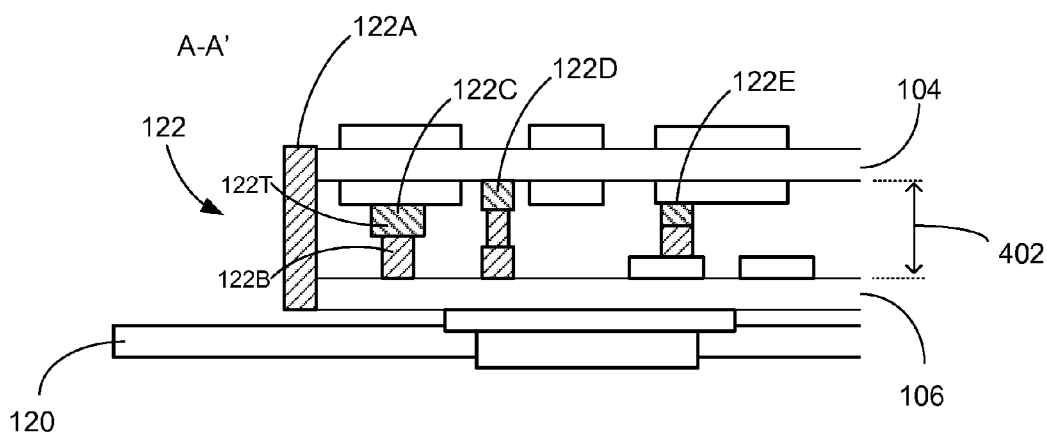


FIG. 3D

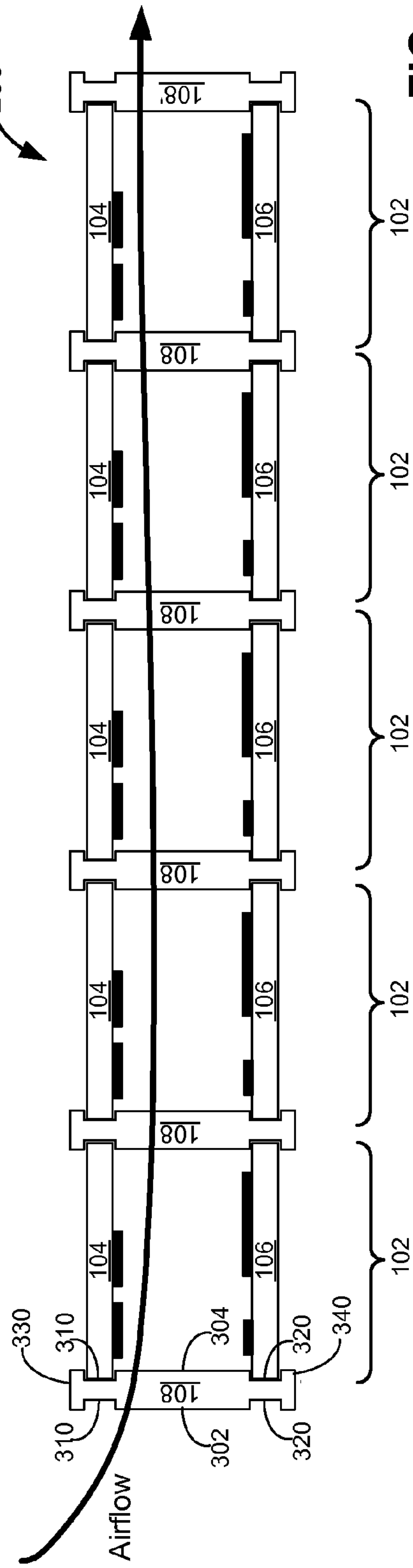

200
108'
104
106
102
108
330
310
304
320
340
302
Airflow

FIG. 4A

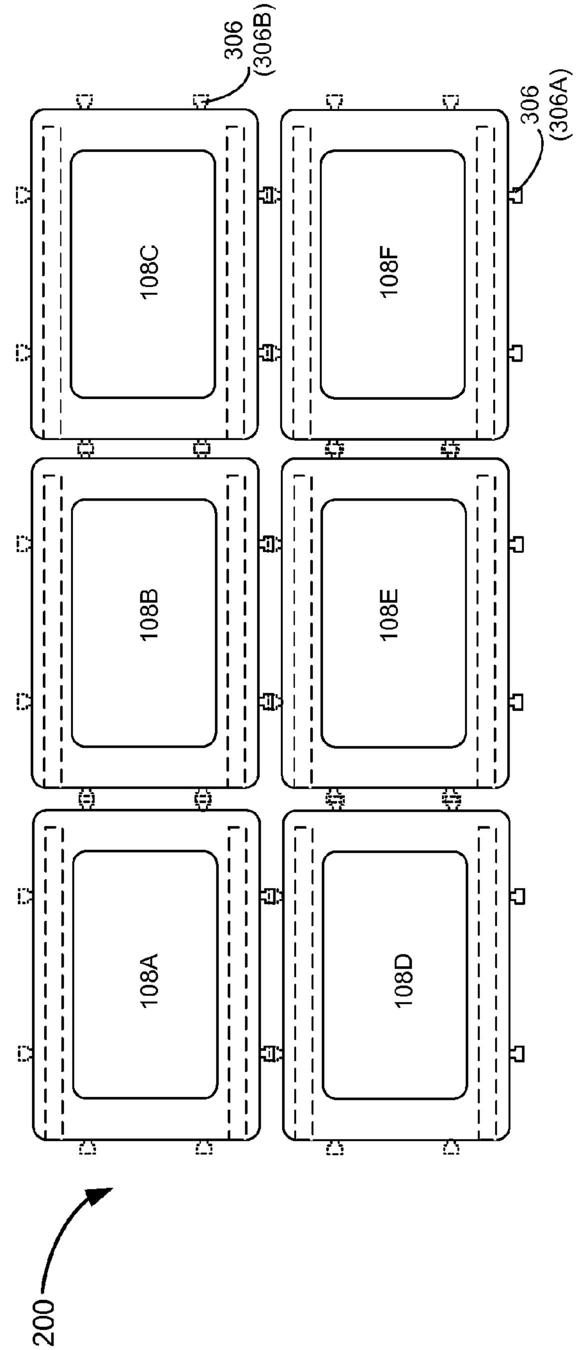

306
(306B)
306
(306A)
108C
108F
108B
108E
108A
108D
200

FIG. 4B

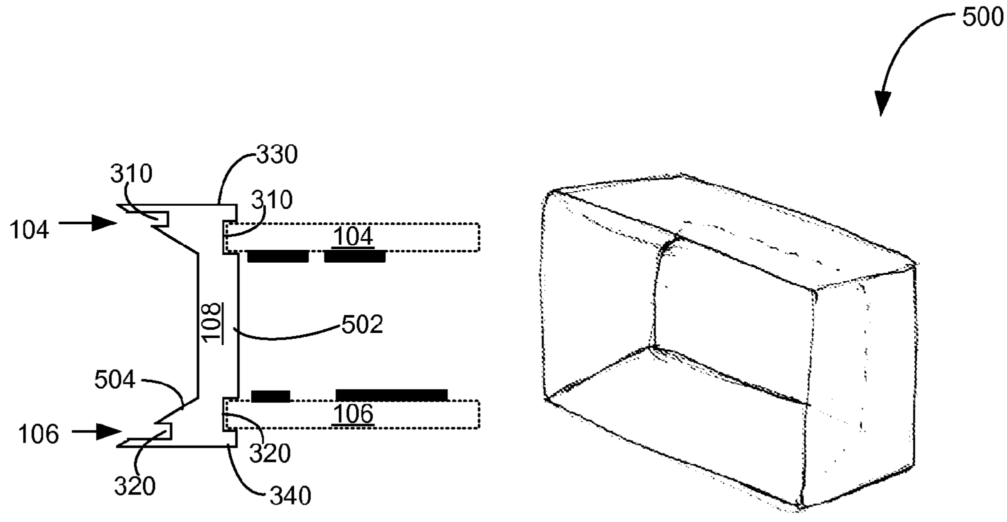

500
330
310
310
104
104
108
502
504
106
106
320
320
340

FIG. 5A

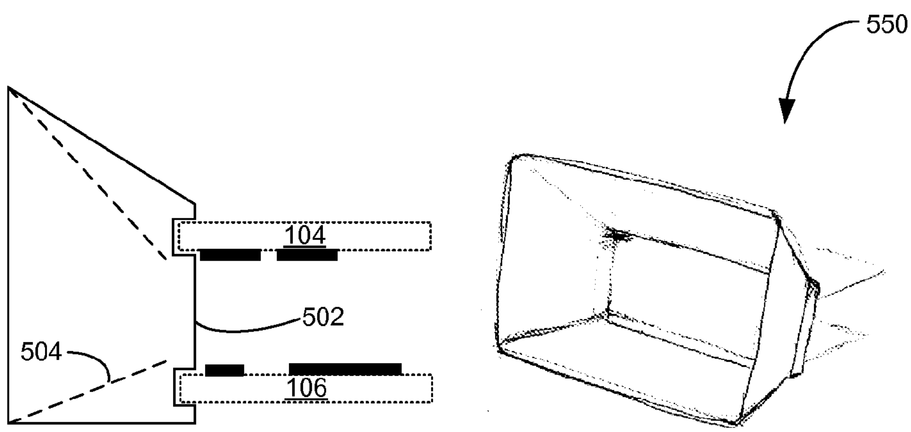
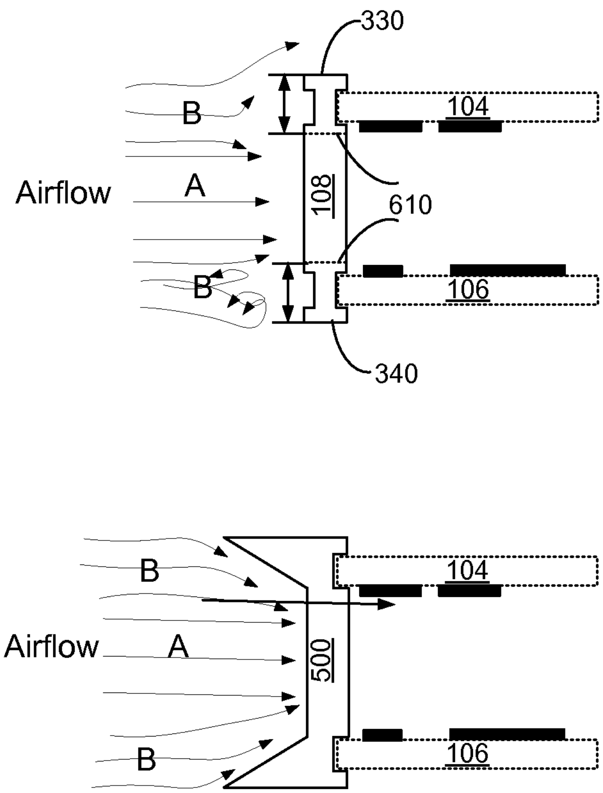
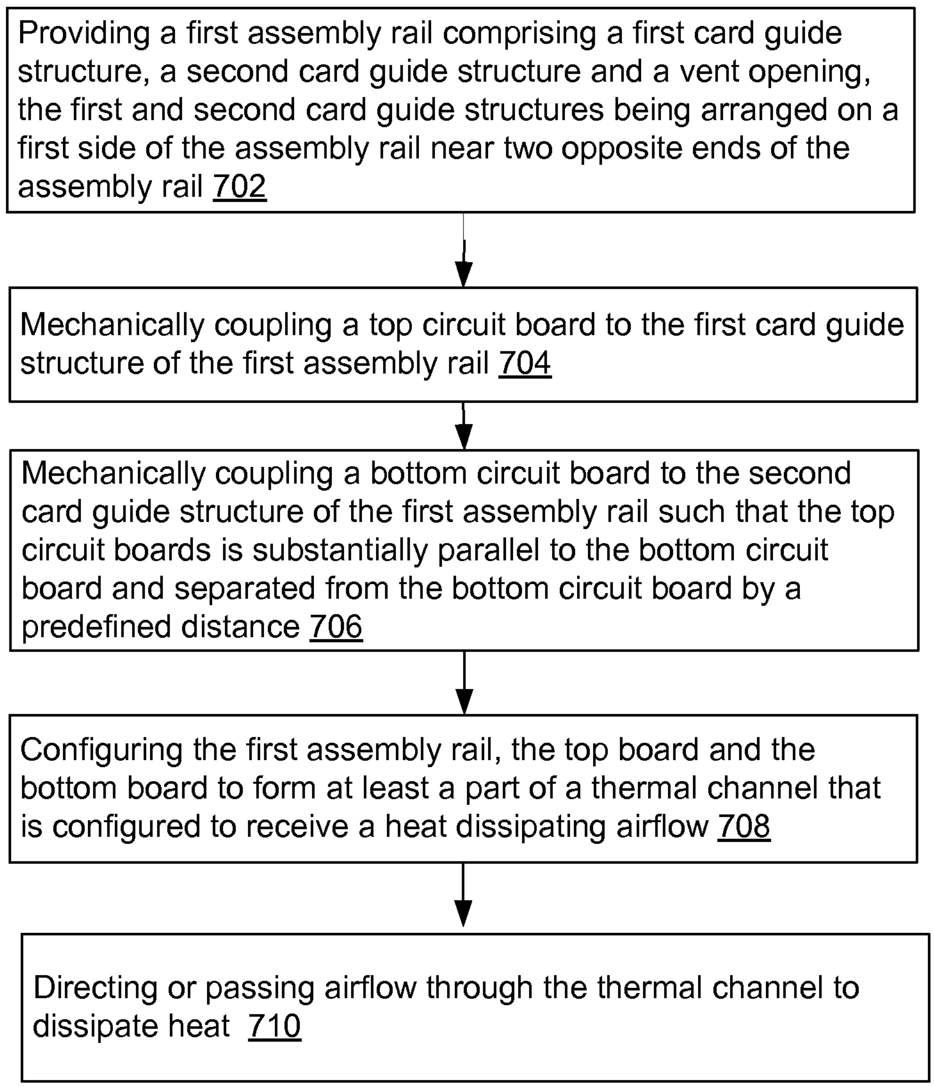

550
104
502
504
106

FIG. 5B



600

FIG. 6


Providing a first assembly rail comprising a first card guide structure, a second card guide structure and a vent opening, the first and second card guide structures being arranged on a first side of the assembly rail near two opposite ends of the assembly rail 702
Mechanically coupling a top circuit board to the first card guide structure of the first assembly rail 704
Mechanically coupling a bottom circuit board to the second card guide structure of the first assembly rail such that the top circuit boards is substantially parallel to the bottom circuit board and separated from the bottom circuit board by a predefined distance 706
Configuring the first assembly rail, the top board and the bottom board to form at least a part of a thermal channel that is configured to receive a heat dissipating airflow 708
Directing or passing airflow through the thermal channel to dissipate heat 710

700

FIG. 7

THERMAL TUBE ASSEMBLY STRUCTURES

RELATED APPLICATIONS

This application claims priority to U.S. Provisional Patent Application Ser. No. 61/953,696, filed Mar. 14, 2014, and titled "Thermal Tube Assembly Structures," which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The disclosed embodiments relate generally to heat management, and in particular, to dissipating heat generated by electronic components in electronic assemblies.

BACKGROUND

Electronics, such as processors or memory, generate heat during operation. If left unchecked, this heat can reduce system performance and even lead to partial or complete system failure. As such, many existing technologies attempt to remove or dissipate heat through the use of heat sinks, cooling fans, etc.

While these technologies may be effective for cooling a single electronic component that is not located near other sources of heat, these technologies fall short when it comes to more complex systems and higher density systems, such as solid state drives (SSDs), dual in-line memory modules (DIMMs), and small outline-DIMMs, all of which utilize memory cells to store data as an electrical charge or voltage.

Existing cooling systems for such systems typically include multiple heat sinks and high-speed fans. These cooling systems are noisy; add significant expense to the system; increase the overall energy consumption of these systems; and decrease system efficiency. Moreover, existing cooling systems do not always alleviate localized hot-spots that form within the systems, which in turn shorten the life of the individual components within the system.

In the absence of efficient heat dissipation mechanisms, the increased heat can ultimately lead to reduced performance or failure of either individual memory cells of a memory module or the entire memory module.

In light of these and other issues, it would be desirable to provide a system and method for more effectively cooling electronic components, especially those found in systems that contain multiple heat generating components.

SUMMARY

According to some embodiments there is provided an electronic assembly that includes a first assembly rail, a top circuit board and a bottom circuit board. The first assembly rail further includes a first card guide structure and a second card guide structure, and the first and second card guide structures are arranged on a first side near two opposite edges of the first assembly rail. The top circuit board is mechanically coupled to the first card guide structure of the first assembly rail, and the bottom circuit board is mechanically coupled to the second card guide structure of the first assembly rail. The top circuit board is substantially parallel to the bottom circuit board, and separated from the bottom circuit board by a predefined distance. The first assembly rail, the top circuit board and the bottom circuit board together form a channel there between for receiving a heat dissipating airflow.

Other embodiments and advantages may be apparent to those skilled in the art in light of the descriptions and drawings in this specification.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the present disclosure can be understood in greater detail, a more particular description may be had by reference to the features of various embodiments, some of which are illustrated in the appended drawings. The appended drawings, however, merely illustrate the more pertinent features of the present disclosure and are therefore not to be considered limiting, for the description may admit to other effective features.

FIG. **1** is a block diagram of an exemplary system module in a typical computational device in accordance with some embodiments.

FIG. **2**A is an isometric view of an exemplary electronic assembly that includes an extended thermal channel formed by circuit boards and assembly rails and in accordance with some embodiments.

FIG. **2**B is another isometric view of the exemplary electronic assembly shown in FIG. **2**A in accordance with some embodiments.

FIG. **3**A is a side view of an exemplary electronic assembly that includes two circuit boards coupled between two assembly rails in accordance with some embodiments.

FIG. **3**B is a front view of the exemplary electronic assembly configured to direct airflow through a vent opening of an assembly rail in accordance with some embodiments.

FIG. **3**C is a cross sectional view of an exemplary electronic assembly that uses a flexible cable to electrically couple two circuit boards in accordance with some embodiments.

FIG. **3**D is a cross sectional view of an exemplary electronic system that includes a rigid tab and/or a rigid interconnect in accordance with some embodiments.

FIG. **4**A is a side view of another exemplary electronic assembly that includes an extended thermal channel formed by a plurality of assembly rails and a plurality of circuit boards in accordance with some embodiments.

FIG. **4**B is a front or cross sectional view of an exemplary electronic assembly that includes a plurality of assembly rails coupled together at their edges in accordance with some embodiments.

FIGS. **5**A and **5**B illustrate a side view and an isometric view of two exemplary assembly rails and each including a respective ducted vent opening and a respective duct portion extended and widened along an airflow direction in accordance with some embodiments.

FIG. **6** is a comparison of the airflow dynamics around a regular vent opening and a ducted vent opening of two exemplary assembly rails in accordance with some embodiments, respectively.

FIG. **7** illustrates an exemplary flow chart of a method for assembling and using an electronic system including a thermal channel in accordance with some embodiments.

In accordance with common practice the various features illustrated in the drawings may not be drawn to scale. Accordingly, the dimensions of the various features may be arbitrarily expanded or reduced for clarity. In addition, some of the drawings may not depict all of the components of a given system, method or device. Finally, like reference numerals may be used to denote like features throughout the specification and figures.

DETAILED DESCRIPTION

The various embodiments described herein include systems, methods and/or devices used or integrated in electronic assemblies. In particular, the electronic assemblies and the heat dissipation method described herein manage airflow that is used to facilitate dissipation of heat generated by electronic components in the electronic systems.

While the embodiments described below primarily describe memory systems, the present inventions are not limited to such. In fact, the present invention applies equally to any electronic systems that require heat dissipation—particularly those systems that include two or more adjacent electronic circuit boards each having components that generate heat.

According to some embodiments there is provided an electronic assembly that includes a first assembly rail, a top circuit board and a bottom circuit board. The first assembly rail further includes a first card guide structure and a second card guide structure, and the first and second card guide structures are arranged on a first side near two opposite edges of the first assembly rail. The top circuit board is mechanically coupled to the first card guide structure of the first assembly rail, and the bottom circuit board is mechanically coupled to the second card guide structure of the first assembly rail. The top circuit board is substantially parallel to the bottom circuit board, and separated from the bottom circuit board by a predefined distance. The first assembly rail, the top circuit board and the bottom circuit board together form a channel there between for receiving a heat dissipating airflow.

In some embodiments, each of the first and second card guide structures includes a respective card guide slot, and a respective edge of each of the top and bottom circuit boards is configured to be inserted and locked into a corresponding card guide slot.

In some embodiments, the channel further includes an additional assembly rail facing, and substantially parallel to, the assembly rail, where the top circuit board and the bottom circuit board are mechanically coupled to the additional assembly rail between the first and second assembly rails.

In some embodiments, the electronic assembly is mechanically coupled to an external electronic system to an end of the channel via the second assembly rail.

In some embodiments, the electronic assembly is mechanically coupled to an external electronic system using one or more mounting fasteners located at an edge of the assembly rail.

In some embodiments, the channel further includes an airflow tab that is coupled to a side of the channel and includes at least one of a rigid material or a flexible cable.

In some embodiments, the top circuit board and the bottom circuit board are electronically coupled to each other via a flexible cable that itself contributes to the channel to further direct the airflow.

In some embodiments, the top circuit board and the bottom circuit board are electronically coupled to each other via one or more rigid electronic interconnects, where the one or more rigid electronic interconnects act as an airflow tab to direct the airflow.

In some embodiments, the top circuit board and the bottom circuit board are electronically coupled to each other via one or more rigid electronic interconnects, where the one or more rigid electronic interconnects are located within the channel and are configured to disturb the airflow.

In some embodiments, the electronic assembly further includes a first set of heat-sensitive electronic components mechanically coupled to one of the top or bottom circuit boards, and a second set of heat-generating electronic components mechanically coupled to the other one of the top or bottom circuit boards. In some embodiments, the electronic assembly further includes a plurality of temperature-sensitive electronic components coupled to a region of the top circuit board that is thermally isolated from other regions of the top circuit board.

In some embodiments, the assembly rail further includes a vent opening at one side of the channel.

In some embodiments, the electronic assembly further includes an additional assembly rail that is mechanically coupled to a second top circuit board and a second bottom circuit board near two opposite ends of the additional assembly rail. The second top and bottom circuit boards being substantially parallel to one another and forming at least a part of a second channel together with the second assembly rail. The additional assembly rail, the second top circuit board, and the second bottom circuit board together form an additional channel there between for receiving a heat dissipating airflow. The channel includes a first channel, and the additional channel is coupled to the first channel on its side.

In some embodiments, the top circuit board includes a first top circuit board, and the bottom circuit board includes a first bottom circuit board. The electronic assembly further includes an additional assembly rail that is mechanically coupled to a second top circuit board and a second bottom circuit board near two opposite ends of a front side of the additional assembly rail. The second top and bottom circuit boards are substantially parallel to one another and form at least a part of a second channel together with the additional assembly rail. The first top and bottom circuit boards are mechanically coupled on a back side of the additional assembly rail to form an extended channel including both the first and second channels, and in accordance with the extended channel, the airflow is directed through a vent opening of the first assembly rail, the space between the first top and bottom circuit boards, a vent opening of the second assembly rail, and space between the second top and bottom circuit boards.

In some embodiments, the assembly rail widens along a direction of the airflow to form a ducted vent opening.

According to another aspect of the invention, there is provided a heat dissipation method that includes providing a first assembly rail. The first assembly rail includes a first card guide structure, a second card guide structure and a vent opening. The first and second card guide structures are arranged on a first side of the assembly rail near two opposite edges of the first assembly rail. The heat dissipation method further includes mechanically coupling a top circuit board to the first card guide structure of the first assembly rail, and mechanically coupling a bottom circuit board to the second card guide structure of the first assembly rail. The top circuit board is substantially parallel to the bottom circuit board, and separated from the bottom circuit board by a predefined distance. Then, the first assembly rail, the top circuit board and the bottom circuit board form at least a part of a thermal channel that is configured to receive a heat dissipating airflow.

Further, according to another aspect of the invention, there is provided an electronic assembly that includes a plurality of assembly rails and a plurality of circuit board sets each further including a top circuit board and a bottom circuit board. The plurality of assembly rails that are arranged substantially in parallel. Each assembly rail includes a respective vent opening, a respective front side and a respective back side. Each side of the respective assembly rail further includes a respective first card guide structure and a respective second card guide structure that are arranged near two opposite edges of the corresponding assembly rail. For each of the plurality of circuit board set, the top circuit board and the bottom circuit board are mechanically coupled between the first card guide structures and between the second card guide structures on two respective sides of two adjacent assembly rails, respectively. The two respective sides face each other. The top circuit board is substantially parallel to the bottom circuit board, and separated from the bottom circuit board by a predefined distance. Further, the plurality of assembly rails alternate with the plurality of circuit board sets and together forms a channel having an extended length and configured to receive a heat dissipating airflow.

In some embodiments, at least one of the plurality of assembly rails is extended and widened along a direction of the airflow on at least one side of the at least one assembly rail to form a ducted vent opening.

Finally, according to another aspect of the invention, there is provided an assembly rail that is configured to form a part of a channel for receiving a heat dissipating airflow. The assembly rail includes a first card guide structure, a second card guide structure and a vent opening. The first card guide structure and the second card guide structure are arranged on a first side of the assembly rail near two opposite ends of the assembly rail and configured to receive a top circuit board and a bottom circuit board, respectively. The vent opening is located between the first card structure and the second card structure, and configured to receive the heat dissipating airflow.

Numerous details are described herein in order to provide a thorough understanding of the example embodiments illustrated in the accompanying drawings. However, some embodiments may be practiced without many of the specific details, and the scope of the claims is only limited by those features and aspects specifically recited in the claims. Furthermore, well-known methods, components, and circuits have not been described in exhaustive detail so as not to unnecessarily obscure more pertinent aspects of the embodiments described herein.

FIG. **1** is a block diagram of an exemplary system module **100** in a typical computational device in accordance with some embodiments. The system module **100** in this computational device includes at least a central processing unit (CPU) **2**, memory modules **4** for storing programs, instructions and data, an input/output (I/O) controller **6**, one or more communication interfaces such as network interfaces **8**, and one or more communication buses **50** for interconnecting these components. In some embodiments, the I/O controller **6** allows the CPU **2** to communicate with an I/O device (e.g., a keyboard, a mouse or a track-pad) via a universal serial bus interface. In some embodiments, the network interfaces **8** includes one or more interfaces for Wi-Fi, Ethernet and Bluetooth networks, each allowing the computational device to exchange data with an external source, e.g., a server or another computational device. In some embodiments, the communication buses **50** include circuitry (sometimes called a chipset) that interconnect and control communications among various system components included in the system module. In some embodiments, the system module **100** includes a motherboard that holds various system components (such as components **2-22**).

In some embodiments, the memory modules **4** include high-speed random access memory, such as DRAM, SRAM, DDR RAM or other random access solid state memory devices. In some embodiments, the memory modules **4** include non-volatile memory, such as one or more magnetic disk storage devices, optical disk storage devices, flash memory devices, or other non-volatile solid state storage devices. In some embodiments, the memory modules **4**, or alternatively the non-volatile memory device(s) within memory modules **4**, include a non-transitory computer readable storage medium. In some embodiments, memory slots are reserved on the system module **100** for receiving the memory modules **4**. Once inserted into the memory slots, the memory modules **4** are integrated into the system module **100**.

In many embodiments, the system module **100** further includes one or more components selected from:

- a memory controller **10** that controls communication between the CPU **2** and memory components, including the memory modules **4**, in the computational device;
- solid state drives (SSDs) **12** that apply integrated circuit assemblies to store data in the computational device, and in many embodiments, are based on NAND or NOR memory configurations;
- a hard drive **14** that is a conventional data storage device used for storing and retrieving digital information based on electromechanical magnetic disks;
- a power supply connector **16** that is electrically coupled to receive an external power supply;
- a power management integrated circuit (PMIC) **18** that modulates the received external power supply to other desired DC voltage levels, e.g., 5V, 3.3V or 1.8V, as required by various components or circuits within the computational device;
- a graphics card **20** that generates a feed of output images to one or more display devices according to their desirable image/video formats; and
- a sound card **22** that facilitates the input and output of audio signals to and from the computational device under control of computer programs.

Further, one of skill in the art would appreciate that other non-transitory computer readable storage media can be used, as new data storage technologies are developed for storing information in the non-transitory computer readable storage media in the memory modules **4** and in the SSDs **12**. These new non-transitory computer readable storage media include, but are not limited to, those manufactured from biological materials, nanowires, carbon nanotubes and individual molecules, even though the respective data storage technologies are currently under development and yet to be commercialized.

Some of the aforementioned components generate heat during normal operation, and therefore, are integrated with separate heat sinks in order to reduce the temperatures of the corresponding components. For example, the SSDs **12** used in a blade server may have heat sinks mounted on the top of each individual dual in-line memory module (DIMM) or on an electronic assembly containing the DIMMs. Heat generated from electronic components in the DIMMs are primarily conducted to the heat sinks, and further dissipated by airflow generated by fans. However, as the data workload in these blade servers increases and the form factor of the DIMMs decreases (e.g., closely placed memory slots in the memory modules **4**), it becomes more difficult for conventional heat sinks and cooling fans to conduct and dissipate the generated heat efficiently.

To address this issue, various embodiments described herein relate to an electronic assembly in which circuit boards are mechanically assembled on assembly rails to form a channel through which airflow generated by an external fan is directed. When the airflow passes along a pathway through the channel, it flows over surfaces of electronic components mounted on the circuit boards and at least partially carries-away heat generated by these components.

In some embodiments, the channel further includes one or two airflow tabs on its sides for controlling the airflow, and each airflow tab is optionally made from a rigid material, a flexible cable or a combination of both. In some embodiments, geometries (e.g., shape and dimensions) of vent openings of the assembly rails are configured to modify the dynamics of the airflow at the entrance and/or the exit of the channel. In some embodiments, locations of the electronic components on the circuit boards are arranged to physically separate heat-sensitive components from other components (such as some heat-generating components). By these means, the channel formed by the assembly rails and the circuit boards may further improve the heat dissipation efficiency of the electronic assembly, in addition to the aforementioned conventional solutions using heat sinks and high-speed fans.

FIG. **2**A is an isometric view of an exemplary electronic assembly **200** that includes a channel **101** formed by the combination of circuit boards and one or more assembly rails. In some implementations, the channel **101** is formed by mechanically coupling one or more duct units **102** to one another. Each duct unit **102** includes at least a top circuit board **104**, a bottom circuit board **106** and an assembly rail **108**. Each duct unit **102** optionally includes an airflow tab **110** to substantially close each side of the duct unit **102**, i.e., enclose the duct on all four sides. When coupled to one another, the duct unit **102** provides an extended length channel **101**. As such, the channel **101** includes an interior airflow pathway bounded by the top circuit board **104**, the bottom circuit board **106**, and the optional airflow tabs **110** of each duct unit **102**. When airflow passes through the interior airflow pathway of the channel **101**, it at least partially carries away the heat generated in the electronic assembly **200**.

In some embodiments, at least one of the top circuit board **104** and bottom circuit board **106** include one or more solid state drives (SSDs). In some embodiments, at least one of the top circuit board **104** and the bottom circuit board **106** include one or more three-dimensional (3D) memory devices.

In some embodiments, the assembly rail **108** or **108**A (e.g., a first assembly rail) acts as a structural frame of each duct unit **102**. The top circuit board **104** and the bottom circuit board **106** are mechanically coupled on a first side (e.g., a back side) near two opposite ends of the assembly rail **112**. The airflow tab **110** is optionally coupled to the assembly rail **108**, the top circuit board **104**, and/or the bottom circuit board **106**. In some implementations, when the electronic assembly **200** only includes one duct unit **102**, the duct unit **102** optionally includes an additional assembly rail **108**B (e.g., a second assembly rail) that is positioned substantially parallel with the first assembly rail **108**. The top and bottom circuit boards **104** and **106** are similarly coupled to the first and second assembly rails **108**A and **108**B but at two opposite edges of the respective circuit board. In this embodiment, the airflow enters the channel **101** from one assembly rail **108**, passes through the space between the top and bottom circuit boards **104** and **106**, and exits from the other assembly rail **108**.

In some embodiments, the electronic assembly **100** includes more than one duct unit **102** (e.g., three duct units—as shown in FIG. **1**) that are coupled to each other. Here, the channel **101** formed by these duct units **102** are aligned with each other to form a channel **101** having an extended length. The assembly rail **108** is optionally coupled at an entrance of the channel **101**, at the interface of two duct units **102**, or at the exit of the channel **101**. When the assembly rail **108** (e.g., rail **108**B) is coupled at the interface of two duct units **102**, it is mechanically coupled not only to the circuit boards of the duct unit **102** which it belongs to, but also to the circuit boards of an adjacent duct unit **102**. Thus, the top circuit board **104** and the bottom circuit board of each duct unit **102** are mechanically coupled between two assembly rails **108** of the electronic assembly **200**.

In some embodiments, assembly rail **108** forms a vent opening **116** through which the airflow passes into the channel **101**. Optionally, the shape of the vent opening **116** is selected from a rectangle, a square, a circle, an oval, a triangle, a diamond and the like. Optionally, corners of the vent opening **116** are rounded. Optionally, the vent opening includes one or more openings configured according to a pattern (e.g., a grill pattern).

In some embodiments, each of the top circuit board **104** and the bottom circuit board **106** is a printed circuit board. Examples of such a circuit board include, but are not limited to, a flash memory board of a solid-state drive (SSD) **112**, a memory board of memory modules **104**, a graphics board of the graphics card **120**, a controller board, a co-processor board, a communication interface, a blank board, or a combination thereof.

Each circuit board **104** or **106** further includes a plurality of electronic components **130** that are mechanically and electrically coupled to a substrate of the respective circuit board **104** or **106**. For example, the electronic components **130** are memory components that are mounted on a memory module. The electronic components **130** are optionally coupled on either side or both sides of the substrate of the respective board **104** or **106**. When the airflow passes through the interior airflow pathway of the channel **101**, heat generated by the plurality of electronic components **130** is at least partially carried away by the airflow. In some embodiments, some electronic components **130** generate substantially more heat or are more sensitive to temperature increases than other components **130**, and such electronic components **130** are preferably mounted on the interior airflow pathway of the channel, e.g., a back side of the top circuit board **104** or a top side of the bottom circuit board **106**.

An airflow tab **110** of the channel **101** (or the duct unit **102**) is optionally made from a rigid tab, a flexible cable or a combination of both. In some embodiments, the rigid tab is mechanically coupled to a third edge of the assembly rail **108**, and the third edge is distinct from the two opposite edges of the assembly rail **108** to which the circuit boards **104** and **106** are coupled. An airflow tab **110** made of the rigid tab avoids the airflow from leaking through the corresponding side of the channel **101**. In some embodiments, the top circuit board **104** and the bottom circuit board **106** are electronically coupled to each other via a rigid tab including one or more rigid electronic interconnects (sometimes called electronic connectors). When such rigid electronic interconnects are located substantially close to a respective edge area of the circuit boards, they perform the same function as the airflow tab **110** to constrain the airflow substantially within the interior airflow pathway of the channel **101**. In some embodiments, the top circuit board **104** and the bottom circuit board **106** are electronically coupled to each other via a flexible cable, and the flexible cable forms another part of the channel to further direct the airflow within the interior airflow pathway. In some embodiments, rigid interconnects and a flexible cable together couple the top and bottom circuit boards **104** and **106**. For instance, two rigid interconnects are coupled to the top circuit board **104** and the bottom circuit board **106**, respectively, and these boards are further coupled together by a flexible cable. Here, the combination of the rigid interconnects and the flexible cable also performs the function of the airflow tab **110** to direct the airflow through the interior airflow pathway of the channel **101**.

In some embodiments, the channel **101** is further coupled to an external electronic system (e.g., a backplate **118**) at one of its two channel ends. The backplate **118** is configured to include a vent opening at a corresponding position according to the position of the vent opening **116** of the assembly rail **108**. The shape and configuration of the vent opening of the backplate **118** are optionally configured according to those of the vent opening **116**. In some embodiments, the airflow that passes through the channel **101** enters from the vent opening of the backplate **118** and flows through the channel **101**, while in some embodiments, the airflow flows through the channel **101**, and exits from the vent opening of the backplate **118**.

In some embodiments, the electronic assembly **100** is mechanically coupled on top of an external component or system **120**, such as a PCI interface card, an ExpressCard housing, a PC card housing, a motherboard of a server, a bus slot of an embedded controller system, or a combination thereof. In one specific example, the electronic assembly **100** constitutes a daughterboard structure, and is assembled directly to a motherboard.

In some embodiments (not shown in FIG. **2**A), the electronic assembly **200** is coupled to one or more heat sinks. The heat sinks are optionally coupled to the electronic components **130** or to the circuit boards **104** and **106** to absorb and dissipate heat generated by the electronic components **130**. In some specific embodiments, a heat sink is coupled between a corresponding assembly rail and an edge of a circuit board (e.g., a top circuit board **104** or a bottom circuit board **106**) as described in U.S. Provisional Application Ser. No. 61/945,674, filed on Feb. 27, 2014, titled "Heat Dissipation for Substrate Assemblies," which is hereby incorporated by reference in its entirety. The heat sink includes a card guide tab and an attachment structure to mechanically couple to the assembly rail and the circuit board edge, respectively. The heat sink optionally includes heat dissipaters to at least partially dissipate the heat that is generated by the electronic components **130** and absorbed by the heat sink.

FIG. **2**B is another isometric view of the exemplary electronic assembly **200** shown in FIG. **2**A in accordance with some embodiments. The electronic assembly **200** includes a plurality of duct units **102** configured to form the channel **101**. The duct units **102** are coupled together to form an extended length channel. In particular, the airflow tab **110** of each duct unit **102** is removed to better illustrate the electronic assembly **200**.

After the duct units **102** are assembled into the electronic assembly **200**, the electronic assembly **200** includes a plurality of assembly rails and a plurality of circuit board sets each including a top circuit board **104** and a bottom circuit board **106**. The plurality of assembly rails **108** alternate with the plurality of circuit board sets and together form the channel **101** that has the extended length. This channel **101** is configured to direct airflow through a respective vent opening **116** of each assembly rail **108** and into the channel between the top and bottom circuit boards **104** and **106** of each circuit board set successively.

Each assembly rail **108** includes a respective vent opening **116**, a respective first side (e.g., a front side) and a respective second side (e.g., a backside). Each side of the respective assembly rail **108** further includes a first card guide structure and a second card guide structure that are arranged near two opposite edges of the respective side of the corresponding assembly rail **108**, respectively.

Each circuit board set is coupled between two adjacent assembly rails **108**. The top circuit board and the bottom circuit board re mechanically coupled between the first card guide structures and between the second card guide structures on two respective sides of two adjacent assembly rails, respectively. The two respective sides of the two adjacent assembly rails face each other. As such, the top circuit board **104** is substantially parallel to the bottom circuit board **106**, and separated from the bottom circuit board **106** by a predefined distance. In a specific example, the predefined distance is determined in accordance with a rail height h of the plurality of assembly rails (including the assembly rails **108**A and **108**B).

In the specific embodiments shown in FIGS. **2**A and **2**B, the channel **101** includes three sets of circuit boards. One skilled in the art knows that the channel **101** may optionally have only one circuit board set that further includes a top circuit board **104** and a bottom circuit board **106** and that the circuit board set is coupled between two adjacent assembly rails **108**.

FIG. **3**A is a side view of an exemplary electronic assembly **300** that includes two circuit boards coupled between two assembly rails **108** in accordance with some embodiments, and FIG. **3**B is a front view of the exemplary electronic assembly **300** configured to direct airflow through a vent opening **116** of an assembly rail **108** in accordance with some embodiments. In the electronic assembly **300**, a top circuit board **104** and a bottom circuit board **106** are mechanically coupled between the two assembly rails **108** (e.g., a first assembly rail **108**A and a second assembly rail **108**B). In some embodiments, the first assembly rail **108**A and the circuit boards **104** and **106** form part of a duct unit **102**, and the duct unit **102** and the second assembly rail **108** are assembled together to form the electronic assembly **300**.

Each assembly rail **108** includes a front side **302** and a back side **304**, and each side of the assembly rail **108** further includes a first card guide structure **310** and a second card guide structure **320**. On each side of the assembly rail **108**, the first and second card guide structures **310** and **320** are arranged near two opposite edges (or ends) **330** and **340** of each assembly rail **108**. The top circuit board **104** is mechanically coupled and locked to the two first card guide structures **310** on the back side **304** of the first assembly rail **108**A and the front side of the second assembly rail **108**B, respectively. The bottom circuit board **106** is mechanically coupled and locked to the two second card guide structures **320** on the back side **304** of the first assembly rail **108**A and the front side of the second assembly rail **108**B, respectively. In some implementations, the first card guide structure **310** and the first card guide structure **320** on each side of the assembly rail **108** are configured to be substantially parallel to each other, such that the top and bottom circuit boards **104** and **106** are also substantially parallel to each other when they are mechanically coupled to the first and second card guide structures **310** and **320**, respectively.

In some embodiments, each card guide structure **310** or **320** includes a respective board guide slot, and a top or bottom circuit board **104**,**106** is inserted and optionally locked into the corresponding board guide slot.

In some embodiments, the assembly rail **108** further includes one or more mounting fasteners **306** on any one of its edges (such as the edges **330**, **340**, **350** and **360**), such that the assembly rail **108** may be mechanically coupled to another component or another assembly rail **108** via the mounting fasteners **306**. In some embodiments, the mounting fasteners **306** (e.g., the fasteners **306**A) are located on a bottom edge **340** of the assembly rail **108** (i.e., externally on the bottom of the channel **101**), and used to mount the electronic assembly **300** on top of an external component or system **120** (e.g., a motherboard). In some embodiments, the mounting fasteners **306** (e.g., the fasteners **306**B) are located on the side edge **350** or **360** of the assembly rail **108** (i.e., externally on a side of the channel **101**). Optionally, the mounting fasteners **306**B on the side edges **350** and **360** are configured to couple an airflow tab **110** to the assembly rail(s) **108**. Optionally, the mounting fasteners **306**B on the side edges **350** and **360** are configured to couple two electronic assemblies **300** side-by-side or couple the electronic assembly **300** to an external component or system (e.g., a motherboard).

Naturally occurring airflow or airflow created by a fan enters the channel **101** via the vent opening **116** of the assembly rail **108**A, passes through the space between the top circuit board **104** and the bottom circuit board **106**, and exits the channel **101** from the vent opening **116** of the assembly rail **108**B. When the assembly rail **108**B is further coupled to a backplate **118**, the airflow further passes through the corresponding vent opening on the backplate **118** after exiting the channel **101**.

In some embodiments, the electronic components **130** of the top circuit board **104** or the bottom circuit board **106** are optionally coupled to one side or on both sides of a respective circuit board. However, in some embodiments, the electronic components **130** are preferably placed in the channel or interior airflow pathway (including the corresponding side of the circuit board that is passed by the airflow) to benefit from the heat dissipation effect provided by the airflow. For example, the electronic components **130** are placed on a back side of the top circuit board **104** or a top side of the bottom circuit board **106**. In some embodiments where an electronic component **130** generates substantially more heat than other electronic components **130** and/or when an electronic component **130** is more sensitive to a temperature increase than other electronic components **130**, the electronic component **130** is placed on the interior airflow pathway. In either embodiment, placing the heat-generating or heat-sensitive electronic components **130** on the interior airflow pathway of the channel **101** allows the generated or absorbed heat to be dissipated more efficiently by the airflow and reduces local temperature increases that could degrade the performances of the corresponding electronic components **130**.

In some embodiments, in addition to placing the electronic components **130** on the interior airflow pathway of the channel **101**, the heat-sensitive electronic components **130** are physically separated from other electronic components, and in particular, separated from the heat-generating electronic components to avoid temperature increases. For example, the heat-sensitive and heat-generating electronic components are located on the top circuit board **104** and the bottom circuit board **106**, respectively. In some embodiments, the heat-sensitive electronic components are disposed at a region of the top circuit board that is thermally isolated from other regions of the top circuit board, and thereby substantially insulated from heat generated by other electronic components on the top and bottom circuit boards.

In some embodiments, the heat-sensitive and heat-generating electronic components are located at two distinct regions of one circuit board (the top circuit board **104** or the bottom circuit board **106**). In some embodiments, the region that includes the heat-sensitive electronic components is positioned upstream in the airflow from the region that includes the other electronic components (including the heat-generating electronic components).

In some embodiments related to memory modules, memory cells are sensitive to temperature increases but they do not generate a large amount of heat. The memory controllers may not be sensitive to temperature increases but themselves generate a relatively larger amount of heat. The heat-sensitive memory cells and the heat-generating memory controllers are positioned on the interior airflow pathway of the channel **101**, and they are separately mounted on two circuit boards or at two distinct regions of one circuit board as discussed above.

FIG. **3**C is a cross sectional view of an exemplary electronic assembly **300** that uses a flexible cable **112** to electrically couple two circuit boards **104** and **106** in accordance with some embodiments. The cross sectional view is optionally associated with a part of the cross section A-A' of the electronic assembly **300** shown in FIG. **3**A. In some embodiments, the electronic assembly **300** is further coupled to an external component or system **120** via mounting fasteners **340** on the assembly rails **108**.

The flexible cable **112** includes a flexible substrate and interconnect that are embedded in the flexible substrate. The interconnect electrically couples the top circuit board **104** and a bottom circuit board **106**, and carries electrical signals between these two circuit boards. The flexible substrate of the flexible cable **112** is made of flexible materials, such as polymeric materials. Examples of the flexible cable **112** include, but are not limited to, a flexible board, flexible wire array, flexible PCB, flexible flat cable, ribbon cable, and a combination thereof.

In some embodiments, the flexible cable **112** becomes a part of an airflow tab on one side of the channel **101** to at least partially direct the airflow that passes the channel **101**. In some implementations, the flexible cable **112** faces another airflow tab **110** that lies close to another opposite edge area of the channel **101**. In some other embodiments, the flexible cable **112** is provided in addition to an existing airflow tab **101**, and faces the other airflow tab **110** that lies close to the other opposite edge area of the channel **101**.

In some implementations, a rigid tab mechanically couples the top circuit board **104** to the bottom circuit board **106** of the duct unit **102** of the electronic assembly **101**. FIG. **3**D is a cross sectional view of an exemplary electronic system **300** that includes a rigid tab **122** in accordance with some embodiments. The cross sectional view is optionally associated with a part of the cross section A-A' of the electronic assembly **300** shown in FIG. **3**A. Here, the rigid tab **122** mechanically couples two circuit boards **104** and **106** together, and broadly includes a rigid tab **122**A and rigid interconnects **122**C-**122**E. As used herein, a rigid interconnect is also called as a rigid connector.

In some embodiments, the rigid tab **122** is positioned substantially close to the corresponding edges of the two circuit boards **104** and **106**, and acts as an airflow tab **110** of the channel **101**. The rigid tab **122** is optionally coupled on an edge of the assembly rail **101** using the fasteners **306**B, or is coupled to the edges of the two circuit boards **104** and **106**.

Optionally, the rigid tab **122** (e.g., the rigid tab **122**A) does not include interconnects, and only mechanically couples the top circuit board **104** and the bottom circuit board **106**. Optionally, the rigid tab **122** (e.g., the rigid tab **122**A and the rigid interconnects **122**C-**122**E) further includes interconnects that electrically and mechanically couples the top circuit board **104** and the bottom circuit board **106**.

In some implementations, one or more of the rigid interconnects **122**C-**122**E are positioned internally within the channel **101**. In some implementations, an internally positioned interconnect **122** is configured to disturb but not block airflow in the thermal channel. As a specific, non-limiting example, when the internally positioned interconnect contains a row of conductive pins, it is preferably oriented to substantially align with the airflow tabs and along the airflow direction.

Optionally, a respective rigid interconnect, such as the rigid interconnect **122**A, includes a single interconnect part that includes two electrical terminals, one electrically coupled to the top circuit board **104** and the other electrically couples to the bottom circuit board **106**. Optionally, a respective rigid interconnect, such as the rigid interconnect **122**C, includes two complimentary interconnect parts **122**T and **122**B, where the interconnect part **122**T is configured to connect to the top circuit board **104**, and the interconnect part **122**B is configured to connect to the bottom circuit board **106**. In addition, the interconnect parts **122**T and **122**B are further pluggable one into the other to form an electrical connection between the top and bottom circuit boards. Optionally, a respective rigid interconnect, such as the rigid interconnect **122**D, includes a set of interconnect parts that has more than two interconnect parts. Two of these interconnect parts are configured to be coupled to the top circuit board **104** and the bottom circuit board **106**, respectively, and furthermore the set of interconnect parts are configured to be assembled into a rigid interconnect that couples the top circuit board **104** to the bottom circuit board **106**.

In some embodiments, the interconnect, whether implemented as the flexible interconnect **112** (shown in FIG. **3**C) or the rigid interconnect **122** (shown in FIG. **3**D), includes a plurality of parallel wires, conductive channels, or signal paths, between the top circuit board **104** and the bottom circuit board **106**. In some embodiments, both ends of the interconnect **112** comprise terminals. For example, in some embodiments, each terminal of rigid interconnect **122** includes a plurality of conductive pins that are assembled on an insulating housing of the rigid interconnect **122**. Each respective terminal of rigid interconnect **122** is optionally configured to be connected to a corresponding circuit board via surface mounting technology or through-hole technology. In some embodiments, conductive pins of the respective terminals are configured to be soldered to conductive pads or via holes that are coated with conductive materials on the corresponding circuit board, thereby forming mechanical and electrical connections with the circuit board.

In some embodiments, the height of the rigid interconnect **122** is commensurate with a separation distance **402**, which is the distance between the top circuit board **104** and the bottom circuit board **106**. Furthermore, in some embodiments, the rail height h of the assembly rail **108** is also commensurate with the separation distance **402** and/or the height of the rigid interconnect **122**.

Optionally, rigid interconnect **122** (e.g., the interconnect **122**A) is attached to respective sides of the top circuit board **104** and the bottom circuit board **106**, and optionally faces another airflow tab attached to opposite sides of the boards. Optionally, the rigid interconnect **122** (e.g., the interconnect **122**C, **122**D or **122**E) is attached to respective inner regions of the top circuit board **104** and the bottom circuit board **106**. In some implementations, two terminals of the rigid interconnect **122** (e.g., the interconnect **122**D) are directly mounted on the top circuit board **104** and the bottom circuit board **106**. In some implementations, one terminal of the rigid interconnect **122** (e.g., the interconnect **122**B) is attached indirectly to a circuit board via an electronic part that is already mounted on the circuit board. In some implementations, both terminals of the rigid interconnect **122** (e.g., the interconnect **122**E) are attached indirectly to the top circuit board **104** and the bottom circuit board **106** via a respective electronic part that is already mounted on the corresponding circuit board. In some implementations, the rigid interconnect **122** is instead a semi-rigid interconnect.

It is noted that an interconnect that electrically couples the top circuit board **104** and the bottom circuit board **106** may also include both a flexible interconnect part and a rigid interconnect part. As a specific example, a rigid interconnect part is coupled to the top circuit board **104** at one end and to a flexible interconnect part at the other end, and the flexible interconnect part further connects to the bottom circuit board **106** or to another rigid interconnect that connects to the bottom circuit board **106**.

In some implementations, as shown in FIG. **3**D, a respective rigid interconnect **122** (e.g., the interconnect **122**E) is attached to respective inner regions of the top circuit board **104** and the bottom circuit board **106** and carries electrical signals between the top circuit board **104** and the bottom circuit board **106**. In some of these implementations, the electronic assembly (or a duct unit of the electronic assembly) also includes one or two airflow tabs **110**, positioned on one or both respective sides of the channel **101**, to constraint airflow between the top and bottom circuit boards **104** and **106**.

In some embodiments, a respective rigid interconnect **122** (e.g., the interconnect **122**A) is positioned at or substantially close to respective edges of the top circuit board **104** and the bottom circuit board **106**. In one example, the rigid interconnect extends substantially the entire length of the duct unit **102**, or substantially the length of the entire the top circuit board **104** and/or the bottom circuit board **106**. In some embodiments, a respective rigid interconnect **122** is used in place of a corresponding airflow tab **110** to control or direct airflow between the top circuit board **104** and the bottom circuit board **106**. In some embodiments, however, a respective rigid interconnect **122** has a length substantially shorter than the length of the duct unit **102**, or substantially shorter than the length of the top circuit board **104** and/or the bottom circuit board **106**.

FIG. **4**A is a side view of another exemplary electronic assembly **200** that includes an extended channel **101** formed by a plurality of assembly rails **108** and a plurality of circuit boards **104** and **106** in accordance with some embodiments. In some implementations, the electronic assembly **200** is formed by coupling a sequence of duct units **102** to each other and optionally attaching an assembly rail **108'** to an end duct unit **108** in the sequence.

Each assembly rail **108** alternates with a circuit board set including a top circuit board **104** and a bottom circuit board **106**. The assembly rails **108** are positioned substantially in parallel and coaligned with each other. After being assembled on the assembly rails **108**, the top circuit boards **104** and the bottom circuit boards **106** in the circuit board sets are also parallel to each other. As such, each circuit board set is mechanically coupled between two substantially parallel assembly rails **108**. Specifically, each assembly rail

108 includes a respective first side (e.g., a front side) and a respective second side (e.g., a back side). Each side of the respective assembly rail **108** further includes a first card guide structure **310** and a second guide structure **320** that are arranged on the respective side near two opposite edges of the corresponding assembly rail **108**, respectively.

In some embodiments, the top circuit board **104** and the bottom circuit board **106** of each circuit board set are coupled on the card guide structures **310** and **320** of two adjacent assembly rails **108** (e.g., a first assembly rail and a second assembly rail), respectively. In particular, the top circuit board **104** is mechanically coupled between a first card guide structure **310**A on a back side of a first assembly rail **108** and another first card guide structure **310**B on a front side of a second assembly rail **108**, and the bottom circuit board **106** is mechanically coupled between a second card guide structure **320**A on the back side of the first assembly rail **108**A and another second card guide structure **320**B on the front side of the second assembly rail **108**B. As such, the top and bottom circuit boards **104** and **106** are substantially parallel to and separated from each other. In one example, and the top and bottom circuit boards **104** and **106** have a separation that is defined in accordance with a rail height h of the plurality of assembly rails.

Each assembly rail **108** further includes a vent opening **116** between the first and second card guide structures. The vent openings **116** of the plurality of assembly rails **108** are aligned to each other, and further aligned to the respective space between the top and bottom circuit boards of each circuit board set, thereby forming an interior airflow pathway for the channel **101**. In accordance with such an interior airflow pathway, airflow is directed through the vent opening of each assembly rail and space between the top and bottom circuit boards of each circuit board set successively.

FIG. **4**B is a front view of an exemplary electronic assembly **200** that includes a plurality of assembly rails **108** coupled together at their edges (e.g., one of the edges **330-360**) in accordance with some embodiments. As explained above, each assembly rail **108** optionally includes mounting fasteners **306** on its edges **330-360**. In some embodiments, the mounting fasteners **306** on two opposite edges (such as the opposite edges **330** and **340**, and the opposite edges **350** and **360**) match with each other, such that every two assembly rails **108** may be coupled to each other via the mounting fasteners **306**. For example, as shown in FIG. **4**B, the mounting fasteners **306**B have allowed every two assembly rails **108**A and **108**B, **108**B and **108**C, **108**D and **108**E, and **108**E and **108**F to mechanically couple to each other on their corresponding opposite edges **350** and **360**. The mounting fasteners **306** have also allowed every two assembly rails **108**A and **108**D, **108**B and **108**E, and **108**C and **108**F to mechanically couple to each other on their corresponding opposite edges **330** and **340**.

Each assembly rail **108** is associated with a respective channel **101** that includes one or more circuit board sets, and is optionally located at an end or an intermediate location of the respective channel **101**. In some embodiments, corresponding duct units **102** of two neighboring thermal channels **101** do not include airflow tabs at their adjacent sides, and the airflow in one of these two neighboring thermal channels **101** freely enters the corresponding airflow pathway of the other channel **101**. In some embodiments, corresponding duct units **102** of two neighboring thermal channels **101** do not include a bottom circuit board **106** and a top circuit board **104**, respectively, and the airflow in one of these two neighboring thermal channels **101** may also freely enter the corresponding airflow pathway of the other channel **101**.

In some embodiments, when multiple thermal channels **101** are coupled to one another as shown in FIG. **4**B, the airflow does not pass over surfaces of electronic components **118** that are coupled externally to each channel **101**, e.g., on a top side of the top circuit board **104** or a back side of the bottom circuit board **106**. Therefore, these externally coupled electronic components **118** does not dissipate heat as efficiently as the electronic components **118** located on the respective interior airflow pathway (i.e., internally in the channel **101**). Therefore, in some embodiments, the electronic components **118** that generate less heat and/or are less sensitive to temperature increases are coupled externally to the respective channel **101**.

FIGS. **5**A and **5**B illustrate a side view and an isometric view of two exemplary assembly rails **500** and **550** each including a respective ducted vent opening **502** extended and widened along an airflow direction in accordance with some embodiments. The respective ducted vent opening **502** further includes a duct portion **504**. Although the duct portions **504** shown in FIGS. **5**A and **5**B are included and configured to extend and widen on one side of the respective assembly rail, they are optionally included, and configured to extend and widen at both sides of the assembly rail. The duct portion **504** optionally guides the airflow to enter or exit the ducted vent opening **502**, when the ducted vent opening **502** is located on an airflow incoming or outgoing side of the assembly rail **500** or **550**, respectively.

As shown in FIG. **5**A, in some embodiments, the duct portion **504** widens from the ducted vent opening **502** to the edges of the assembly rail **500**. Optionally, the assembly rail **500** replaces one or both end assembly rails **108** that are coupled at the ends of the channel **101**, while being preferably used on an airflow incoming end of the channel **101**. Optionally, the assembly rail **500** is used at an intermediate assembly rail **108** of the channel **101** to control the airflow that passes through the interior airflow pathway of the channel **101**. In some embodiments, the assembly rail **500** includes card guide structures **310** and **320** on a respective duct portion **504** of the duct vent opening **502**. The card guide structures **310** and **320** are still located near the two opposite edges **330** and **340** of the assembly rail **400**, such that a top circuit board **104** and a bottom circuit board **106** may be assembled to the assembly rail **500** if needed.

As shown in FIG. **5**B, in some embodiments, the duct portion **504** of the ducted vent opening **502** widens beyond the assembly rail edges **330-360** around the vent opening **502**. Geometric configurations and dimensions of the duct portion **504** are configured according to specific airflow dynamics requirements. In some embodiments, the duct portion **504** of the ducted vent opening **502** in the assembly rail **550** is substantially wider than the duct portion **504** of the ducted vent opening **502** in the assembly rail **500**. The assembly rail **550** is preferably used on an airflow incoming end of the channel **101**, although it may also be used on an airflow outgoing end of the channel **101**, or at an intermediate assembly rail **108** of the channel **101**. In some embodiments, the assembly rail **550** includes card guide structures **310** and **320** on a respective duct portion **504**, such that a top circuit board **104** and a bottom circuit board **106** may be assembled to the assembly rail **500**.

One skilled in the art knows that the assembly rails **500** and **550** having the ducted venting openings **502** may also act as structural frames to assemble the electronic assembly

200 shown in FIGS. 2A-2B, 3A-3D and 4A-4B. For brevity, the analogous details are not repeated here.

FIG. 6 is a comparison 600 of the airflow dynamics around a regular vent opening 116 and a ducted vent opening 502 of two exemplary assembly rails 108 and 500 in accordance with some embodiments, respectively. Here, the assembly rails 108 and 500 are used at an airflow inlet end of the channel 101. A part (e.g., part A) of incoming airflow easily enters the regular vent opening of the assembly rail 108, and however, another part (e.g., part B) of the inlet airflow hits an edge area between an edge 330 or 340 of the assembly rail 108 and an edge 610 of the regular vent opening 116. The part B of the incoming airflow causes turbulence around the edge area, and is ultimately blocked from entering or redirected into the vent opening 116. Such a blocked or redirected part B of the incoming airflow reduces the amount of the air that enters the channel 101, and thereby compromises the flow rate of the airflow in the channel 101.

In contrast, as shown in FIG. 6B, the part B of the incoming airflow are guided by the duct portion 504 and enters the ducted vent opening 116 when the assembly rail 500 is applied at the airflow incoming end of the channel 101. Such a directed airflow improves the amount of the air that enters the channel 101 and the flow rate of the airflow in the channel 101, and the overall heat dissipation efficiency of the electronic assembly 200 are thereby enhanced.

FIG. 7 illustrates an exemplary flow chart of a method for assembling and using an electronic system 200 including a channel in accordance with some embodiments. A first assembly rail is provided (702). The first assembly rail includes a first card guide structure, a second card guide structure and a vent opening. The first and second card guide structures are arranged on a first side of the first assembly rail near two opposite edges of the first assembly rail. In some embodiments, the first assembly rail acts as a structural frame to assemble components (e.g., circuit boards and airflow tabs) of the channel thereon. A top circuit board is mechanically coupled (704) to the first card guide structure of the first assembly rail, and a bottom circuit board is mechanically coupled (706) to the second card guide structure of the first assembly rail. The top circuit board is substantially parallel to the top circuit board and separated from the bottom circuit board by a predefined distance. In some embodiments, each of the first and second card guide structures includes a card guide slot where a circuit board is inserted and locked. The first assembly rail, the top circuit board and the bottom circuit board are configured (708) to form at least a part of the thermal channel, and the channel is configured to receive a heat dissipating airflow.

In some embodiments, the channel has an extended length, when the electronic system 200 includes a plurality of assembly rails and a plurality of circuit board sets each further including a top circuit board and a bottom circuit board. Each circuit board set is assembled with an assembly rail to form a duct unit according to operations 702-708. Each circuit board of a duct unit is further coupled to an assembly rail of a neighboring duct unit or another stand-alone assembly rail at an end of the thermal channel. As such, the extended channel is formed by successively coupling two or more duct units together.

Thereafter, airflow is passed or directed (710) through the channel to dissipate heat, as described above.

More details and examples of the components of the channel (e.g., the circuit boards and the assembly rails) are discussed above with reference to FIGS. 2A-2B, 3A-3D, 4A-4B and 5A-5B.

In accordance with various embodiments of the invention, assembly rails function as structural frames to conveniently assemble a plurality of circuit boards together, and form an electronic assembly including a thermal channel. Such an electronic assembly offers an easy, flexible and inexpensive solution to manufacture and assemble daughter card assemblies that are configured to integrate with a motherboard for many electronic devices. More importantly, airflow is directed through the channel in a controlled manner. When the electronic components of the electronic assembly are placed in accordance with configurations of an interior airflow pathway of the thermal channel, the airflow efficiently carries away the heat generated by these electronic components, maintains a low temperature increase for these electronic components and reduces the thermal expansion of the corresponding circuit boards. In some implementations, heat-sensitive electronic components are isolated from other electronic components, and placed at an upstream location in the interior airflow pathway. Under some circumstances, the heat-sensitive electronic components and other electronic components may have a temperature difference of 20° C. as a result of using the thermal channel.

As noted above, in some embodiments, the electronic assembly 200 or 300 described herein includes one or more memory modules, and in some embodiments, the electronic components of the electronic assembly 200 or 300 include semiconductor memory devices or elements. The semiconductor memory devices include volatile memory devices, such as dynamic random access memory ("DRAM") or static random access memory ("SRAM") devices, non-volatile memory devices, such as resistive random access memory ("ReRAM"), electrically erasable programmable read only memory ("EEPROM"), flash memory (which can also be considered a subset of EEPROM), ferroelectric random access memory ("FRAM"), and magnetoresistive random access memory ("MRAM"), and other semiconductor elements capable of storing information. Furthermore, each type of memory device may have different configurations. For example, flash memory devices may be configured in a NAND or a NOR configuration.

The memory devices can be formed from passive elements, active elements, or both. By way of non-limiting example, passive semiconductor memory elements include ReRAM device elements, which in some embodiments include a resistivity switching storage element, such as an anti-fuse, phase change material, etc., and optionally a steering element, such as a diode, etc. Further by way of non-limiting example, active semiconductor memory elements include EEPROM and flash memory device elements, which in some embodiments include elements containing a charge storage region, such as a floating gate, conductive nanoparticles or a charge storage dielectric material.

Multiple memory elements may be configured so that they are connected in series or such that each element is individually accessible. By way of non-limiting example, NAND devices contain memory elements (e.g., devices containing a charge storage region) connected in series. For example, a NAND memory array may be configured so that the array is composed of multiple strings of memory in which each string is composed of multiple memory elements sharing a single bit line and accessed as a group. In contrast, memory elements may be configured so that each element is individually accessible, e.g., a NOR memory array. One of skill in the art will recognize that the NAND and NOR memory configurations are exemplary, and memory elements may be otherwise configured.

The semiconductor memory elements included in a single device, such as memory elements located within and/or over the same substrate or in a single die, may be distributed in a two- or three-dimensional manner (such as a two dimensional (2D) memory array structure or a three dimensional (3D) memory array structure).

In a two dimensional memory structure, the semiconductor memory elements are arranged in a single plane or single memory device level. Typically, in a two dimensional memory structure, memory elements are located in a plane (e.g., in an x-z direction plane) which extends substantially parallel to a major surface of a substrate that supports the memory elements. The substrate may be a wafer on which the material layers of the memory elements are deposited and/or in which memory elements are formed or it may be a carrier substrate which is attached to the memory elements after they are formed.

The memory elements may be arranged in the single memory device level in an ordered array, such as in a plurality of rows and/or columns. However, the memory elements may be arranged in non-regular or non-orthogonal configurations as understood by one of skill in the art. The memory elements may each have two or more electrodes or contact lines, including a bit line and a word line.

A three dimensional memory array is organized so that memory elements occupy multiple planes or multiple device levels, forming a structure in three dimensions (i.e., in the x, y and z directions, where the y direction is substantially perpendicular and the x and z directions are substantially parallel to the major surface of the substrate).

As a non-limiting example, each plane in a three dimensional memory array structure may be physically located in two dimensions (one memory level) with multiple two dimensional memory levels to form a three dimensional memory array structure. As another non-limiting example, a three dimensional memory array may be physically structured as multiple vertical columns (e.g., columns extending substantially perpendicular to the major surface of the substrate in the y direction) having multiple elements in each column and therefore having elements spanning several vertically stacked planes of memory devices. The columns may be arranged in a two dimensional configuration, e.g., in an x-z plane, thereby resulting in a three dimensional arrangement of memory elements. One of skill in the art will understand that other configurations of memory elements in three dimensions will also constitute a three dimensional memory array.

By way of non-limiting example, in a three dimensional NAND memory array, the memory elements may be connected together to form a NAND string within a single plane, sometimes called a horizontal (e.g., x-z) plane for ease of discussion. Alternatively, the memory elements may be connected together to extend through multiple parallel planes. Other three dimensional configurations can be envisioned wherein some NAND strings contain memory elements in a single plane of memory elements (sometimes called a memory level) while other strings contain memory elements which extend through multiple parallel planes (sometimes called parallel memory levels). Three dimensional memory arrays may also be designed in a NOR configuration and in a ReRAM configuration.

A monolithic three dimensional memory array is one in which multiple planes of memory elements (also called multiple memory levels) are formed above and/or within a single substrate, such as a semiconductor wafer, according to a sequence of manufacturing operations. In a monolithic 3D memory array, the material layers forming a respective memory level, such as the topmost memory level, are located on top of the material layers forming an underlying memory level, but on the same single substrate. In some implementations, adjacent memory levels of a monolithic 3D memory array optionally share at least one material layer, while in other implementations adjacent memory levels have intervening material layers separating them.

In contrast, two dimensional memory arrays may be formed separately and then integrated together to form a non-monolithic 3D memory device in a hybrid manner. For example, stacked memories have been constructed by forming 2D memory levels on separate substrates and integrating the formed 2D memory levels atop each other. The substrate of each 2D memory level may be thinned or removed prior to integrating it into a 3D memory device. As the individual memory levels are formed on separate substrates, the resulting 3D memory arrays are not monolithic three dimensional memory arrays.

Further, more than one memory array selected from 2D memory arrays and 3D memory arrays (monolithic or hybrid) may be formed separately and then packaged together to form a stacked-chip memory device. A stacked-chip memory device includes multiple planes or layers of memory devices, sometimes called memory levels.

The term "three-dimensional memory device" (or 3D memory device) is herein defined to mean a memory device having multiple layers or multiple levels (e.g., sometimes called multiple memory levels) of memory elements, including any of the following: a memory device having a monolithic or non-monolithic 3D memory array, some non-limiting examples of which are described above; or two or more 2D and/or 3D memory devices, packaged together to form a stacked-chip memory device, some non-limiting examples of which are described above.

A person skilled in the art will recognize that the invention or inventions descried and claimed herein are not limited to the two dimensional and three dimensional exemplary structures described here, and instead cover all relevant memory structures suitable for implementing the invention or inventions as described herein and as understood by one skilled in the art.

It will be understood that, although the terms "first," "second," etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first contact could be termed a second contact, and, similarly, a second contact could be termed a first contact, which changing the meaning of the description, so long as all occurrences of the "first contact" are renamed consistently and all occurrences of the second contact are renamed consistently. The first contact and the second contact are both contacts, but they are not the same contact.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the claims. As used in the description of the embodiments and the appended claims, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will also be understood that the term "and/or" as used herein refers to and encompasses any and all possible combinations of one or more of the associated listed items. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

As used herein, the term "if" may be construed to mean "when" or "upon" or "in response to determining" or "in accordance with a determination" or "in response to detecting," that a stated condition precedent is true, depending on the context. Similarly, the phrase "if it is determined [that a stated condition precedent is true]" or "if [a stated condition precedent is true]" or "when [a stated condition precedent is true]" may be construed to mean "upon determining" or "in response to determining" or "in accordance with a determination" or "upon detecting" or "in response to detecting" that the stated condition precedent is true, depending on the context.

The foregoing description, for purpose of explanation, has been described with reference to specific embodiments. However, the illustrative discussions above are not intended to be exhaustive or to limit the claims to the precise forms disclosed. Many modifications and variations are possible in view of the above teachings. The embodiments were chosen and described in order to best explain principles of operation and practical applications, to thereby enable others skilled in the art.

What is claimed is:

1. An electronic assembly, comprising:

a first assembly rail comprising a first card guide structure, a second card guide structure and a first vent opening between the first guide structure and the second guide structure, the first card guide structure and the second card guide structure being arranged on a first side of the first assembly rail near two opposite ends of the first assembly rail;

a second assembly rail facing the first side of the first assembly rail, the second assembly rail comprising a third card guide structure, a fourth card guide structure, a fifth card guide structure, a sixth card guide structure and a second vent opening between the third guide structure and the fourth guide structure and between the fifth guide structure and the sixth guide structure, the third card guide structure and the fourth card guide structure being arranged on a first side of the second assembly rail near two opposite ends of the second assembly rail, the fifth card guide structure and the sixth card guide structure being arranged on a second side of the second assembly rail near the two opposite ends of the second assembly rail;

a first top circuit board having a first end and an opposing second end, the first end and the second end of the first top circuit board are mechanically coupled to the first card guide structure of the first assembly rail and the third card guide structure of the second assembly rail, respectively;

a first bottom circuit board having a first end and an opposing second end, the first end and the second end of the first bottom circuit board are mechanically coupled to the second card guide structure of the first assembly rail and the fourth card guide structure of the second assembly rail, respectively such that the first top circuit board is substantially parallel to the first bottom circuit board and the first top circuit board is separated from the first bottom circuit board by a predefined distance;

a second top circuit board having a first end and a second end, the first end of the second top circuit board is mechanically coupled to the fifth card guide structure of the second assembly rail such that the first top circuit board and the second top circuit board are substantially coplanar; and

a second bottom circuit board having a first end and a second end, the first end of the second bottom circuit board is mechanically coupled to the sixth card guide structure of the second assembly rail such that the first bottom circuit board and the second bottom circuit board are substantially coplanar,

wherein the first assembly rail, the first top circuit board, and the first bottom circuit board together form a first channel there between for receiving a heat dissipating airflow,

wherein the second assembly rail, the second top circuit board, and the second bottom circuit board together form a second channel there between for receiving the heat dissipating airflow, and

wherein the first channel is coupled to the second channel via the second vent opening such that the heat dissipating airflow is directed through the first vent opening, the space between the first top and bottom circuit boards, the second vent opening, and the space between the second top and bottom circuit boards.

2. The electronic assembly of claim **1**, wherein each of the first and second card guide structures includes a respective card guide slot, and a respective first end of each of the first top and bottom circuit boards is configured to be inserted and locked into a corresponding card guide slot.

3. The electronic assembly of claim **1**, wherein the electronic assembly is mechanically coupled to an external electronic system at an end of the second channel via the second assembly rail.

4. The electronic assembly of claim **1**, wherein the electronic assembly is mechanically coupled to an external electronic system using one or more mounting fasteners located at an edge of the first assembly rail.

5. The electronic assembly of claim **1**, wherein the first channel further comprises an airflow tab that is coupled to a side of the first channel and includes at least one of a rigid material or a flexible cable.

6. The electronic assembly of claim **1**, wherein the first top circuit board and the first bottom circuit board are electronically coupled to each other via a flexible cable that itself contributes to the first channel to further direct the airflow.

7. The electronic assembly of claim **1**, wherein the first top circuit board and the first bottom circuit board are electronically coupled to each other via one or more rigid electronic interconnects, where the one or more rigid electronic interconnects act as an airflow tab to direct the airflow.

8. The electronic assembly of claim **1**, wherein the first top circuit board and the first bottom circuit board are electronically coupled to each other via one or more rigid electronic interconnects, where the one or more rigid electronic interconnects are located within the first channel and are configured to disturb the airflow.

9. The electronic assembly of claim **1**, further comprising a first set of heat-sensitive electronic components mechanically coupled to one of the first top or bottom circuit boards, and a second set of heat-generating electronic components mechanically coupled to the other one of the first top or bottom circuit boards.

10. The electronic assembly of claim **1**, further comprising a plurality of temperature-sensitive electronic components coupled to a region of the first top circuit board that is thermally isolated from other regions of the first top circuit board.

11. The electronic assembly of claim 1, wherein the first vent opening is arranged at one side of the first channel.

12. The electronic assembly of claim 1, wherein the first assembly rail widens along a direction of the airflow such that the first vent opening forms a ducted vent opening.

13. The electronic assembly of claim 1, wherein at least one of the first top circuit board and first bottom circuit boards comprises one or more solid state drives (SSDs) or one or more three-dimensional (3D) memory devices.

14. A method for dissipating heat of an electronic assembly, comprising:

providing a first assembly rail comprising a first card guide structure, a second card guide structure and a first vent opening, the first and second card guide structures being arranged on a first side of the first assembly rail near two opposite ends of the first assembly rail;

providing a second assembly rail facing the first side of the first assembly rail, the second assembly rail comprising a third card guide structure, a fourth card guide structure, a fifth card guide structure, a sixth card guide structure and a second vent opening, the third and fourth card guide structures being arranged on a first side of the second assembly rail near two opposite ends of the second assembly rail, the fifth and sixth card guide structures being arranged on a second side of the second assembly rail near the two opposite ends of the second assembly rail;

providing a first top circuit board, a first bottom circuit board, a second top circuit board, and a second bottom circuit board, each circuit board having a first end and a second end;

mechanically coupling the first end and the second end of the first top circuit board to the first card guide structure of the first assembly rail and the third card guide structure of the second assembly rail, respectively;

mechanically coupling the first end and the second end of the first bottom circuit board to the second card guide structure of the first assembly rail and the fourth card guide structure of the second assembly rail, respectively such that the first top circuit board is substantially parallel to the first bottom circuit board and the first top circuit board is separated from the first bottom circuit board by a predefined distance;

mechanically coupling the first end of the second top circuit board to the fifth card guide structure of the second assembly rail such that the first top circuit board and the second top circuit board are substantially coplanar;

mechanically coupling the first end of the second bottom circuit board to the sixth card guide structure of the second assembly rail such that the first bottom circuit board and the second bottom circuit board are substantially coplanar;

configuring the first assembly rail, the first top circuit board and the first bottom circuit board to form a first channel that is configured to receive a heat dissipating airflow; and

configuring the second assembly rail, the second top circuit board, and the second bottom circuit board to form a second channel that is configured to receive the heat dissipating airflow,

wherein the first channel is coupled to the second channel via the second vent opening such that the heat dissipating airflow is directed through the first vent opening, the space between the first top and bottom circuit boards, the second vent opening, and the space between the second top and bottom circuit boards.

15. The method of claim 14, wherein a plurality of temperature-sensitive electronic components are coupled to a region of the first top circuit board, the region of the first top circuit board is thermally isolated from other regions of the first top circuit board.

16. The method of claim 14, wherein the first assembly rail is extended and widened along a direction of the airflow on at least one side of the first assembly rail such that the first vent opening forms a ducted vent opening.

17. The method of claim 14, further comprising directing airflow through a space formed between the first top circuit board and the first bottom circuit board to dissipate heat.

18. The method of claim 14, wherein at least one of the first top circuit board and the first bottom circuit boards comprises one or more solid state drives (SSDs) or one or more three-dimensional (3D) memory devices.

19. An electronic assembly, comprising:

a plurality of assembly rails that are arranged substantially in parallel, each assembly rail comprising a respective vent opening, a respective front side and a respective back side, each side of the respective assembly rail further comprising a respective first card guide structure and a respective second card guide structure that are arranged near two opposite ends of the assembly rail; and

a plurality of circuit board sets each comprising a top circuit board and a bottom circuit board, each top circuit board and bottom circuit having a first end and a second end, the first end and the second end of the top circuit board and the first end and the second end of the bottom circuit board being mechanically coupled between the first card guide structures and between the second card guide structures on two respective sides of two adjacent assembly rails, respectively, wherein the two respective sides face each other, the top and bottom circuit boards being substantially parallel to each other and separated by a predefined distance, the top circuit boards in the plurality of circuit board sets being substantially coplanar, the bottom circuit boards in the plurality of circuit board sets being substantially coplanar;

wherein the plurality of assembly rails alternate with the plurality of circuit board sets and each assembly rail and each circuit board set adjacent thereto together form a channel there between for receiving a heat dissipating airflow,

wherein each channel is coupled to each other via the respective vent opening such that the heat dissipating airflow is directed alternately through each vent opening and the space between the top and bottom circuits of each circuit board set.

20. The electronic assembly of claim 19, wherein at least one of the plurality of assembly rails is extended and widened along a direction of the airflow on at least one side of the at least one assembly rail to form a ducted vent opening.

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